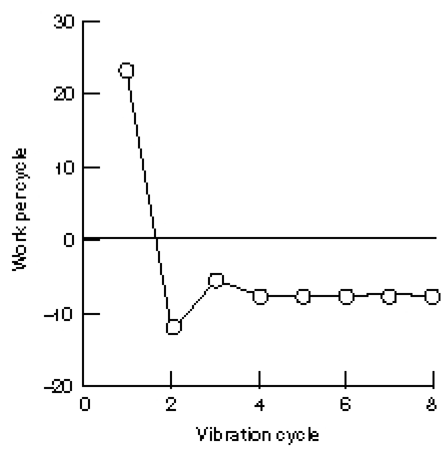
TURBO-AE: An Aeroelastic Code for Propulsion Applications

NASA's Advanced Subsonic Technology (AST) program is developing new technologies to increase the fuel efficiency of commercial aircraft engines, improve the safety of engine operation, and reduce engine emissions and noise. With the development of new designs for ducted fans, compressors, and turbines to achieve these goals, a basic aeroelastic requirement is that there should be no flutter or high resonant blade stresses in the operating regime. To verify the aeroelastic soundness of these designs, we need an accurate prediction and analysis code. Such a two-dimensional viscous propulsion aeroelastic code, named TURBO-AE, is being developed at the NASA Lewis Research Center.

The TURBO-AE aeroelastic code is based on a three-dimensional unsteady aerodynamic Euler/Navier-Stokes turbomachinery code TURBO, developed under a grant from NASA Lewis. TURBO-AE can model viscous flow effects that play an important role in certain aeroelastic problems, such as flutter with flow separation (or stall flutter) and flutter in the presence of shock and boundary-layer interaction. The structural dynamics representation of the blade in the TURBO-AE code is based on a normal mode representation. A finite-element analysis code, such as NASTRAN, is used to calculate in-vacuum vibration modes and the associated natural frequency.

A work-per-cycle approach is used to determine aeroelastic (flutter) stability. With this approach, the motion of the blade is prescribed to be a harmonic vibration in a specified in-vacuum normal mode. The aerodynamic forces acting on the vibrating blade and the work done by these forces on the vibrating blade during a cycle of vibration are calculated. If positive work is being done on the blade by the aerodynamic forces, the blade is dynamically unstable, since it will extract energy from the flow, leading to an increase in the amplitude of the blade's oscillation.



Aeroelastic work-per-cycle for a blade vibrating in the first mode.

Initial calculations have been done for a configuration representative of the Energy Efficient Engine fan rotor. The accompanying figure shows the work-per-cycle after each cycle of vibration. It can be seen that the work-per-cycle does not vary much after the fourth cycle. The negative sign of the converged work-per-cycle shows that the fan blade is dynamically stable and will not flutter.

TURBO-AE will provide a useful aeroelastic prediction/analysis capability for engine manufacturers. It will reduce design cycle times by allowing new blade designs to be verified for aeroelastic soundness before blades are built and tested. With this prediction capability, it will be possible to build thinner, lighter, and faster rotating blades without encountering aeroelastic problems like stall flutter and high-cycle fatigue due to forced vibrations.

Bibliography

Bakhle, M.A., et al.: Development of an Aeroelastic Code Based on an Euler/Navier-Stokes Aerodynamic Solver. ASME Paper 96-GT-311, 1996.

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